PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : B22F 3/00, C22C 1/04, 27/04 F42B 1/032 — A1

(11) International Publication Number: WO 92/20481

(43) International Publication Date: 26 November 1992 (26.11.92)

(21) International Application Number: PCT/SE92/00251

(22) International Filing Date: 16 April 1992 (16.04.92)

(30) Priority data:
9101500-8 17 May 1991 (17.05.91) SE

(71) Applicant *(for all designated States except US)*: POWDER TECH SWEDEN AB [SE/SE]; Björnövägen 12, S-723 45 Västerås (SE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : HEDE, Allan [SE/SE]; Aggerudsvägen 20, S-691 44 Karlskoga (SE). LARSSON, Hans, Gunnar [SE/SE]; Eriksgatan 24, S-724 60 Västerås (SE).

(74) Agent: BERGGREN, Björn; Långrevsgatan 1, S-723 49 Västerås (SE).

(81) Designated States: AT (European patent), BE (European patent), BR, CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GB (European patent), GR (European patent), IT (European patent), JP, LU (European patent), MC (European patent), NL (European patent), NO, PL, SE (European patent), US.

Published
With international search report.
With amended claims.
In English translation (filed in Swedish).

(54) Title: ALLOY WITH HIGH DENSITY AND HIGH DUCTILITY

(57) Abstract

The invention relates to a method of manufacturing an Ni-base alloy with high density and high ductility and objects made of said alloy. The method is characterized in that an alloy containing 15-70 % (per cent by weight) W and/or Ta, 0-25 % Fe, 0-15 % Si and 0-2 % Mn, is manufactured by means of a powder metallurgical process, suitably in equipment producing fine particle sizes in the powder.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FI	Finland	ML	Mali
AU	Australia	FR	France	MN	Mongolia
BB	Barbados	GA	Gabon	MR	Mauritania
BE	Belgium	GB	United Kingdom	MW	Malawi
BF	Burkina Faso	GN	Guinea	NL	Netherlands
BG	Bulgaria	GR	Greece	NO	Norway
BJ	Benin	HU	Hungary	PL	Poland
BR	Brazil	IE	Ireland	RO	Romania
CA	Canada	IT	Italy	RU	Russian Federation
CF	Central African Republic	JP	Japan	SD	Sudan
CG	Congo	KP	Democratic People's Republic of Korea	SE	Sweden
CH	Switzerland			SN	Senegal
CI	Côte d'Ivoire	KR	Republic of Korea	SU	Soviet Union
CM	Cameroon	LI	Liechtenstein	TD	Chad
CS	Czechoslovakia	LK	Sri Lanka	TG	Togo
DE	Germany	LU	Luxembourg	US	United States of America
DK	Denmark	MC	Monaco		
ES	Spain	MG	Madagascar		

Alloy with high density and high ductility

Technical Field

The invention relates to a method of manufacturing an Ni-base alloy with high density and high ductility and objects made of said alloy.

Background Art

High-density material is of interest for many applications, both civilian and military. For civilian applications these materials are useful for counterweights, gyros and certain blasting purposes, while for military applications they are useful for high-efficiency active parts against fighter aircraft, armoured vehicles, missiles, ships and other armoured targets.

The high-density material may be included in the form of pre-fragmented shell, such as in explosive shells in the form of pellets, such as pellet explosive shells, and pellet-based active parts in the form of arrow-shaped rods such as in modern arrow ammunition. In recent years high-density material has also become of interest for active parts based on the directed explosive action principle (DEA), and has been developed in order to combat armoured targets as well as for various civilian purposes. The explosive action is achieved by the metal-liner (usually in the form of a cone or cap) included in the DEA charge forming a jet or projectile with extremely high initial velocity (> 5 km/s) and thus high penetration capacity into armoured targets. Hitherto extremely pure copper with fine particle size and minimum texture has been used for these liners for jet-producing DEA.

Efforts have been made to improve the penetration capacity for DEA charges by gradually improving and developing all the parts and a material has been aimed at for the liner material that would have greater density than copper while retaining the same properties in other respects, i.e. soft and with great ductility at fast deformation, and also a melting point not deviating too far from that of copper. Two other important requirements are that the material should be fine-particled and texture-free.

In order to achieve these properties the use has been proposed of either a heavy-metal composite with 40-90% W, or an alloy with approximately the same composition as the tough binder phase in Ni-Fe heavy metal, i.e. approximately 55% Ni, 25% Fe and 20% W.

However, the heavy-metal composite proved to be not very suitable as DEA material since it was not sufficiently tough at rapid deformation processes. Interest has therefore

been focussed recently on the tough binder-phase alloy. This alloy cannot be manufactured using melt metallurgical methods, due to its high segregation tendency and consequent brittleness. The use of powder metallurgical methods has therefore been proposed, primarily sintering or hot isostatic pressing of a fine-particled mixture of the pure metal powders. Gas atomized powder has also been indicated as possible starting powder. In all experiments performed alloy compositions were aimed at having W contents of between 15 and 30% and Ni and Fe contents in a proportion of 7:3 since this Ni/Fe ratio has proved best for heavy metal from the tenacity aspect. In some cases Co were included, while elements such as Si, Mn and others were deemed "poisons". However, no particularly good DEA results were reported when using these alloys, probably because the alloys were not a hundred per cent single phase, sufficiently pure, with sufficiently low oxygen content (= low surface oxygen content in the powder), etc. These alloys were produced by sintering processes.

Summary of the Invention

The invention aims at a solution of the problems described above and problems associated therewith. The invention relates to a method of manufacturing an alloy containing 15-70 per cent by weight W and/or Ta, 0-25 per cent by weight Fe, 0-1 per cent by weight Si and 0-2 per cent by weight Mn, by means of a powder metallurgical process. This should preferably be carried out in installations that produce fine powder particle sizes. In order to achieve the desired properties for jet-producing DEA (= high density, high ductility) the alloy used shall suitably be a single phase alloy. The alloy powder should suitably be produced by a method giving low oxygen content, such as gas atomization. An alloy consisting of 25-40 per cent by weight W, max. 10 per cent by weight Fe, approximately 0.1 per cent by weight Si (or similar deoxidant) and the rest Ni may be used, and a starting powder with high purity and low surface oxygen content. Multi-phase alloys, i.e. alloys containing 40-70 per cent by weight W, may also be considered for projectile-forming DEA. In the alloys used W and/or Ta are not used as composite material, and these alloys are initially just melt compositions. The alloy shall suitably contain 50-70 per cent by weight Ni, preferably 55-65%.

Detailed information and examples

The alloy used for the method according to the invention shall thus contain 15-70% W, 0-25% Fe, 0-1% Si and 0-2% Mn + the normal impurities. The alloy shall preferably contain 25-40% W, max. 0-25% Fe, and the rest Ni (per cent by weight).

The following may be mentioned as examples of alloys used in the method according to the invention:

Alloy 1: 0.01% C, 0.05% Si, 0.05% Mn, 57% Ni, 22% Fe and 21% W;
Alloy 2: 0.03% C, 0.14% Si, 0.23% Mn, 62% Ni, 9% Fe and 29% W;
Alloy 3: 0.02% C, 0.12% Si, 0.16% Mn, 65% Ni and 35% W;

The properties of these alloys may be classified as follows:

	Yield point Mpa	Elongation %	Density g/cm
Alloy 1	260	54	10.4
Alloy 2	290	46	11.5
Alloy 3	320	48	12.3

Fine-particled powder of the alloy according to the invention was produced by means of gas atomizing, suitably in installations giving fine powder particle size and low surface oxygen content. The powder is suitably filled into metal capsules and subjected to hot isostatic pressing (HIP). Test rods were manufactured by hot isostatic pressing of such cylindrical metal capsules filled with powder. Prior to manufacture of the test rods the compacted blanks were quench annealed at temperatures from 1200°C and 1250°C.

The invention thus covers methods of manufacture that produce objects with better properties than objects, copper-based and others, already known.

The method can be exemplified as follows:

Powder metallurgical manufacture from a starting material consisting of extremely pure, gas atomized powder with low surface oxygen content and small powder particle size.

Gas atomizing in powder plants, which produces powder of the type described above.

Compacting the powder by means of cold compacting, sintering or pressure sintering (HIP, sinter-HIP, etc.) to semi-manufactured products for further cold or hot working to almost finished form with certain subsequent machining, or to finished form without

subsequent machining. The method according to the invention (see above) entails great advantages with regard to performance and cost in comparison with conventional processes.

Experiments with alloys and methods according to the invention have shown the following:

The highest possible density in single-phase Ni-Fe-W-alloys (i.e. without the occurrence of free W in the structure), is achieved in Fe-free or almost Fe-free Ni-base alloys. After quench annealing from 1200^{o}C an Fe-free alloy may contain approximately 40% W in stable solution. The density of such an alloy will be about 13 g/cm.

The highest possible W-content achievable in a melt that can be atomized is approximately 65%. An Ni-65% W alloy is two-phase and gives a density of approximately 15.5 g/cm.

High ductility (> 30%) can be achieved with single-phase Ni-Fe-W-alloys having a W content of 15-40% and Ni/Fe ratio >> 7:3 if they are manufactured using powder metallurgical methods as described below and quench annealed from a temperature of at least about 1000-1100^{o}C after compacting, or quick-cooled in conjunction with compacting.

To enable high ductility to be achieved, a starting powder must be used that has low surface oxygen content and fine powder particle size. The method of manufacture according to the invention gives such a powder.

The invention also relates to a method of manufacturing active parts for DEA ammunition. Alloys according to the invention have been tested and the following been found:
These alloys are extremely suitable for such purposes and produce a marked increase in the efficiency of such ammunition when used against armoured targets with directed explosive action. These parts are suitably manufactured by encapsulating the powder in metal, followed by hot isostatic pressing, or by means of cold compacting or dynamic compacting (explosion compacting or punch compacting). The aim is to achieve full density.

The alloy may be included as binder between pellets of W or other heavy metal, for instance in cylindrical, sleeve-shaped ammunition, or in conical parts, the latter manufactured by means of punch compacting or pressure turning. The compacting may possibly be followed by sintering.

The invention can be varied in many ways within the scope of the following claims.

CLAIMS

1. A method of manufacturing an Ni-base alloy with high density and high ductility and objects made of said alloy, characterized in that an alloy containing 15-70 per cent by weight W and/or Ta, 0-25 per cent by weight Fe, 0-1 per cent by weight Si and 0-2 per cent by weight Mn, is manufactured by means of a powder metallurgical process.

2. A method as claimed in claim 1, characterized in that the alloy powder is manufactured by means of a method giving low oxygen content, such as gas atomizing.

3. A method as claimed in claim 1 or 2, characterized in that the alloy produced in powder form is consolidated to active parts in high-efficiency ammunition, such as for directed explosive action.

4. A method as claimed in any of the preceding claims, characterized in that the objects produced, e.g. active parts, are manufactured by means of metal encapsulation and hot isostatic pressing (HIP).

5. A method as claimed in any of claims 1-3, characterized in that the objects produced, e.g. active parts, are manufactured by means of cold compacting, possibly followed by HIP, in order to achieve full density.

6. A method as claimed in claim 4 or 5, characterized in that the active parts are produced as blanks by means of hot or cold compacting powder, and that these blanks are thereafter shaped to their final form by means of cold-merge compression, pressure turning and similar methods.

7. A method as claimed in any of claims 4-6, characterized in that the active parts are produced using the alloys as binder between pellets and fragments which in turn contain W or some other heavy metal, in cylindrical, tubular ammunition, for instance, or in conical ammunition parts.

8. A method as claimed in any of the preceding claims, characterized in that the objects, e.g. the active parts are manufactured by means of hot or cold compacting or by means of dynamic compacting (explosion or punch compacting) to full density, possibly followed by sintering.

AMENDED CLAIMS
[received by the International Bureau on 22 September 1992 (22.09.92); original claims 1-8 replaced by amended claims 1-8 (1 page)]

1. A method of manufacturing an Ni-base alloy with high density and high ductility, characterized in that an alloy containing 15-70 per cent by weight W and/or Ta, 0-25 per cent by weight Fe, 0-1 per cent by weight Si and 0-2 per cent by weight Mn, is manufactured as a gas atomized powder of pure melt compositions of the alloy.

2. A method as claimed in claim 1, characterized in that the alloy powder is manufactured by means of a method giving low oxygen content, such as gas atomizing.

3. A method as claimed in claim 1 or 2, characterized in that the alloy produced in powder form is consolidated to active parts in high-efficiency ammunition, such as for directed explosive action.

4. A method as claimed in any of the preceding claims, characterized in that the objects produced, e.g. active parts, are manufactured by means of metal encapsulation and hot isostatic pressing (HIP).

5. A method as claimed in any of claims 1-3, characterized in that the objects produced, e.g. active parts, are manufactured by means of cold compacting, possibly followed by HIP, in order to achieve full density.

6. A method as claimed in claim 4 or 5, characterized in that the active parts are produced as blanks by means of hot or cold compacting powder, and that these blanks are thereafter shaped to their final form by means of cold-merge compression, pressure turning and similar methods.

7. A method as claimed in any of claims 4-6, characterized in that the active parts are produced using the alloys as binder between pellets and fragments which in turn contain W or some other heavy metal, in cylindrical, tubular ammunition, for instance, or in conical ammunition parts.

8. A method as claimed in any of the preceding claims, characterized in that the objects, e.g. the active parts are manufactured by means of hot or cold compacting or by means of dynamic compacting (explosion or punch compacting) to full density, possibly followed by sintering.

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE 92/00251

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: B 22 F 3/00, C 22 C 1/04, C 22 C 27/04
F 42 B 1/032

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	C 22 C; F 42 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
X	US, A, 3988118 (ROBERT GRIERSON ET AL) 26 October 1976, see column 3, line 19 - line 33; column 5 - column 6 --	1-8
X	US, A, 4762559 (THOMAS W. PENRICE ET AL) 9 August 1988, see column 1, line 1 - line 30; column 5, line 1 - column 6, line 31 --	1-8
X	US, A, 4784690 (JAMES A. MULLENDORE) 15 November 1988, see column 1, line 1 - line 37; column 3, line 19 - column 4, line 12 --	1-8

* Special categories of cited documents:[10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
20th August 1992	1992 -08- 27
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	Nils Engnell Nils Engnell

Form PCT/ISA/210 (second sheet) (January 1985)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
X	US, A, 4851042 (ANIMESH BOSE ET AL) 25 July 1989, see column 1, line 44 - column 2, line 10 --	1-8
X A	GB, A, 747714 (THE PLESSEY COMPANY LIMITED) 11 April 1956, see page 2, line 87 - page 3, line 11 --	1 2-8
T	Scand. J. Metallurgy 20, Vol. 20, 1991 Lars B. Ekbom: "Tungsten heavy metals", see page 190 - page 197 --	1-8

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.PCT/SE 92/00251

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 01/07/92
The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 3988118	76-10-26	NONE	
US-A- 4762559	88-08-09	EP-A- 0304181	89-02-22
US-A- 4784690	88-11-15	NONE	
US-A- 4851042	89-07-25	US-A- 4801330	89-01-31
GB-A- 747714	56-04-11	NONE	